

Johnson Space Center: ES4

Assessing Flaw Detectability of Flash Infrared Thermography in Graphite/Epoxy

Laminated Composites

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NASA MUST Paper: Infrared Thermography of Graphite/Epoxy

Abstract

The focus of this project is to use Infrared Thermography, a non-destructive test, to detect detrimental cracks and voids beneath the surface of materials used in the space program. This project will consist of developing a simulation model of the Infrared Thermography inspection of the Graphite/Epoxy specimen. The simulation entails finding the correct physical properties for this specimen as well as programming the model for thick voids or flat bottom holes. After the simulation is completed, an Infrared Thermography inspection of the actual specimen will be made. Upon acquiring the experimental test data, an analysis of the data for the actual experiment will occur, which includes analyzing images, graphical analysis, and analyzing numerical data received from the infrared camera. The simulation will then be corrected for any discrepancies between it and the actual experiment. The optimized simulation material property inputs can then be used for new simulation for thin voids. The comparison of the two simulations, the simulation for the thick void and the simulation for the thin void, provides a correlation between the peak contrast ratio and peak time ratio. This correlation is used in the evaluation of flash thermography data during the evaluation of delaminations.

Goals and Purpose

The goal of creating these simulations is to understand what the IM7 graphite/epoxy composite will look like even before using Infrared Thermography. By creating the computer simulation, there can now be a general idea of the smallest size cracks that Infrared Thermography will be able to detect.

The first simulation created was a simulation of the actual composite itself, which contained flat-bottom holes. For the simulation to work, there must be uniform thickness throughout the piece. Since the composite has six different thicknesses, it had to be split up into six different sections. Also the simulation only uses square voids; therefore the circular defects in the composite must be converted to square defects that cover the same area. After deciding on how many pixels wide a defect should be, a ratio of the width of a defect to the number of pixels was set. This ratio can then be used to create the rest of the simulation, since we know all the dimensions of the composite. The only other information needed is the thermal properties of both the composite and the defects, which are filled with air. After researching the thermal properties of both the composite and the defects, the values for each were found and input into the simulation. After all the data for the simulation has been obtained, the simulation can then be run.

After the simulation is run, the simulation data can then be put into an excel spread sheet where the normalized contrast can be calculated (**Formula 1**). After the normalized contrast has been calculated, a graphical representation of the normalized contrast is created with respect to time.

Formula 1: The formula for the Normalized Contrast between two points:

$$\frac{I_1 - I_2}{I_1 + I_2} \quad 1$$

After the simulation of the six different sections of the composite is completed, and the graphs of the normalized contrast have been created, then we can run the actual experiment. By creating a simulation that is exactly like the actual composite, the actual experiment can be used to test the validity of the simulation.

To collect the experimental data, a computer, infrared camera, two flash bulbs, a hood, and computer software, Echotherm, were used. The Infrared Camera was placed in the middle of the two flash bulbs perpendicular to the specimen. The hood was placed around the flash bulbs and infrared camera enclosing the bulbs, Infrared Camera, and specimen in the same area.

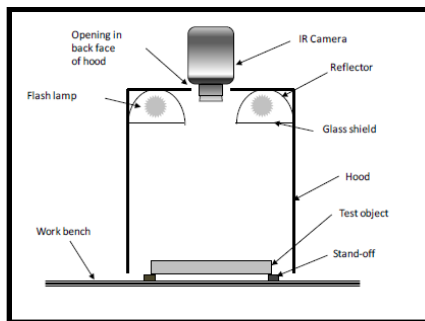


Fig. 6 Layout of the equipment used for the Infrared Thermography experiment

Once the button “Run” was pushed each bulb sent a 15 KJ flash of light onto the front surface of the specimen which caused the front surface to heat up. The Infrared Camera, which

¹ P_i = current temperature at the point of interest
 P_{i0} = initial temperature at the point of interest
 P_r = current temperature at the reference point
 P_{r0} = initial temperature at the reference point

had been running before the flash occurred, continues to record as the specimen cools. The video acquisition time was 7 seconds and the frame rate is 60Hz [3]. The computer shows the averaged image frames.

After selecting points of interest, which lie in the center of the defect, and reference points, which are not in a defect but have the same initial temperature as the defect, data can then be collected from the Temperature v. Time graph that can be displayed in the Ecotherm. This data can then be put into an excel spread sheet and the normalized contrast can be calculated. The same formula as **Formula 1** is used, except the initial temperatures are the averages of the pre-flash data.

After creating graphs for the experimental data's normalized contrast, the experimental graphs were compared to the simulation graphs. It was decided that the fit was inadequate. We then looked at the various properties of the composite that may be different from what was originally assumed.

The properties with which we could work with were, the density, heat capacity, and conductivity. The density should not be changed, since we obtained the density for the specific material being used in the experiment. It was also discovered that we should not change the heat capacity because by doing so it causes the voids to end up cooler than their surroundings, which is not possible. Therefore we decided to increase the conductivity value of the Graphite/Epoxy composite in order to decrease its' peak contrast and peak time. However, while increasing the conductivity the 3:1 ratio of conductivity in-plane and out-of-plane of was maintained. After running the simulation with the changed values the simulation was optimized.

The next goal is to change the flat bottom hole simulation to a thin delamination or void simulation which more accurately depicts the thin delaminations which occur in materials. The

results of the thin gap simulation were graphed, and compared with the results of flat-bottom hole simulation. By comparing these two simulations, a ratio was found that could then be used to accurately calculate the size of thin delaminations shown in the Infrared Thermography evaluation.

Impact of MUST Internship

The MUST internship has allowed me to gain knowledge about a field I did not know existed. I was able learn a new field of Engineering, work in a team environment, gain experience in a high-tech laboratory setting, and perform research that will later be used as the initial building blocks of a larger project. I learned about Thermodynamics, Infrared Thermography, Ultrasonic Testing, Eddy Current testing, Welding, and Destructive Testing while at Johnson Space Center.

Since I am planning on going to graduate school, being able to perform research and write a technical paper has helped to give me a head start on writing scholarly papers. The research that I have performed here will also serve as a stepping stone to my capstone project for my university.

My mentor has been very gracious and helpful during my entire internship. I was able to sit in on meetings that dealt with the orbiter and the use of nondestructive testing of poppets. This was a great experience because I was able to see how the work we do impacts other branches and projects. I was also taken to Ellington field to observe a training session on Infrared Thermography. Overall, this internship has peaked my interest in Nondestructive Testing and I may decide to pursue this field of study.